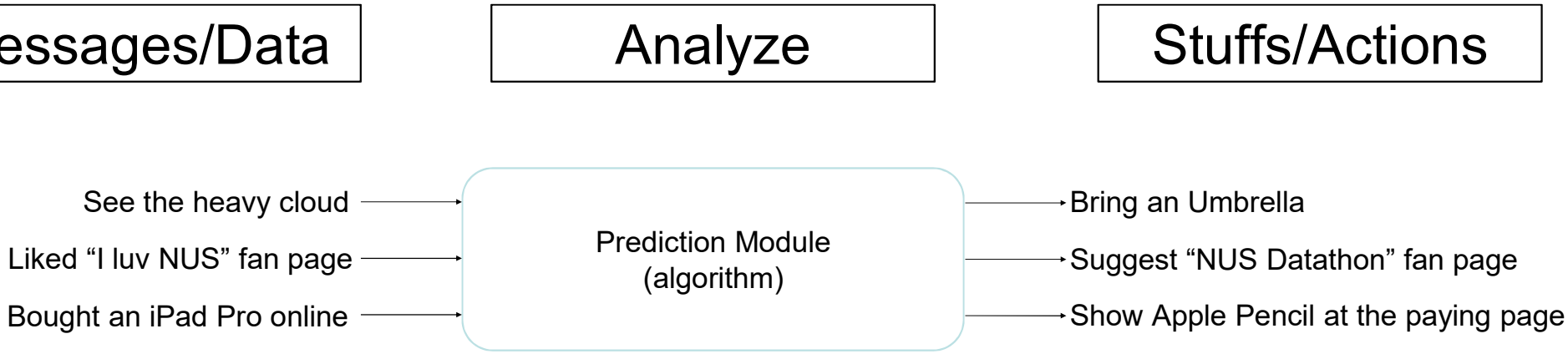
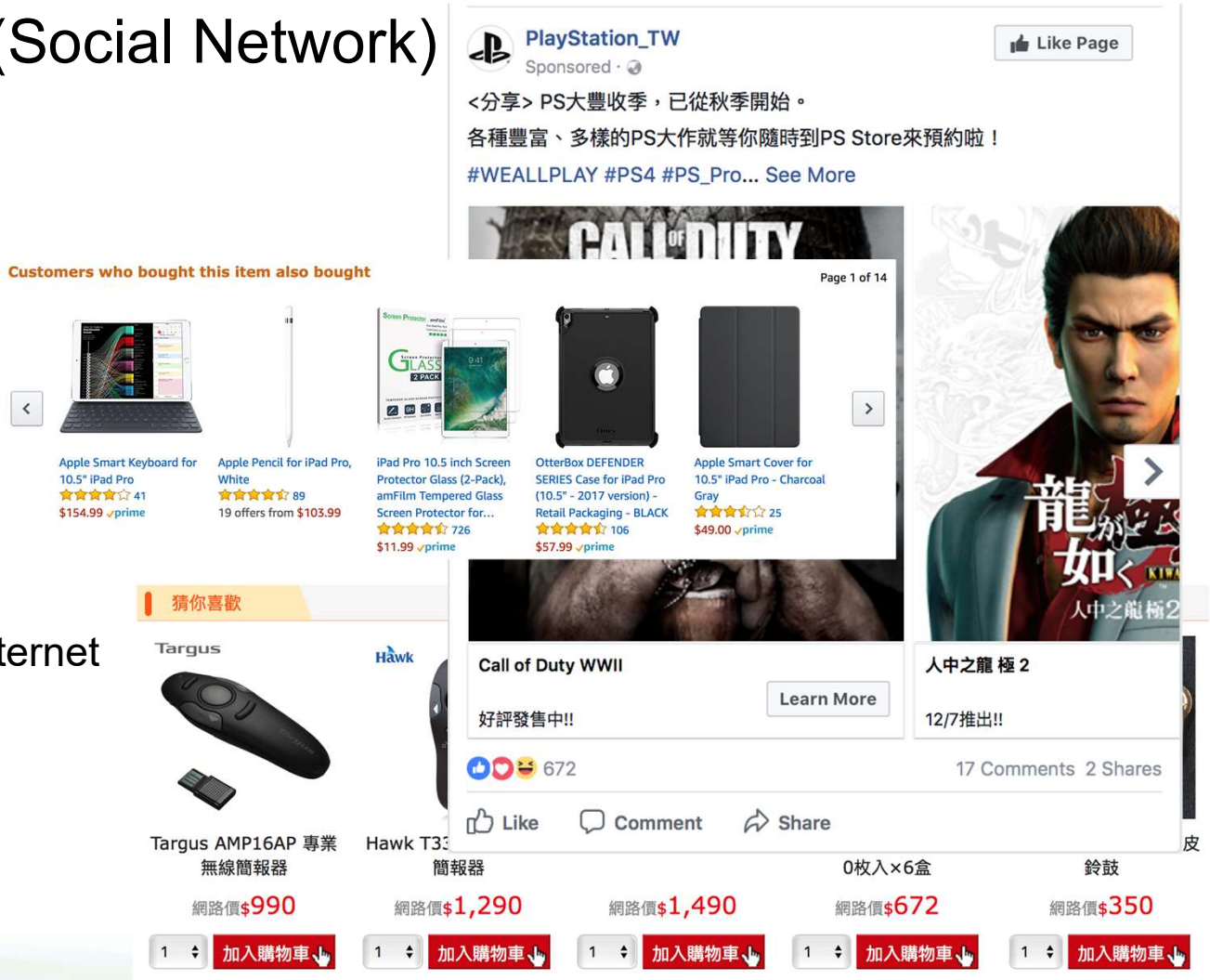
Predictive Module Impact

Does Predictive Modules impacts you and I? How or how is it not?

Predictive Modules



Predictive Modules Usage (Social Network)



Predictive modules around us in the Internet

But did these really affects our lives?

Predictive Module Usage Comparison

With IoT

Without IoT

-102 StarHub 5:54 PM

Singapore, West Region

HOURLY 48 Hours →

TIME	COND	TEMP	PRECIP	WIND
6 PM		27°	50%	NNE 28 KMH
7 PM		28°	0%	NNE 24 KMH
8 PM		28°	0%	NNE 21 KMH
9 PM		27°	0%	NNE 18 KMH
10 PM		26°	0%	NNE 11 KMH

DAILY 15 Days →

SUN	MON	TUE	WED	THU
-- 25°	32° 24°	30° 24°	30° 24°	31° 25°
50%	10%	80%	90%	10%

Differences with and without IoT

With IoT	*Without IoT*
Concrete actions after prediction	*No actions after prediction*
Prediction really impacts something	*Prediction hardly impacts*
Accuracy can be firmed	*Accuracy is not considered*
Real consequences	*Inconveniences*

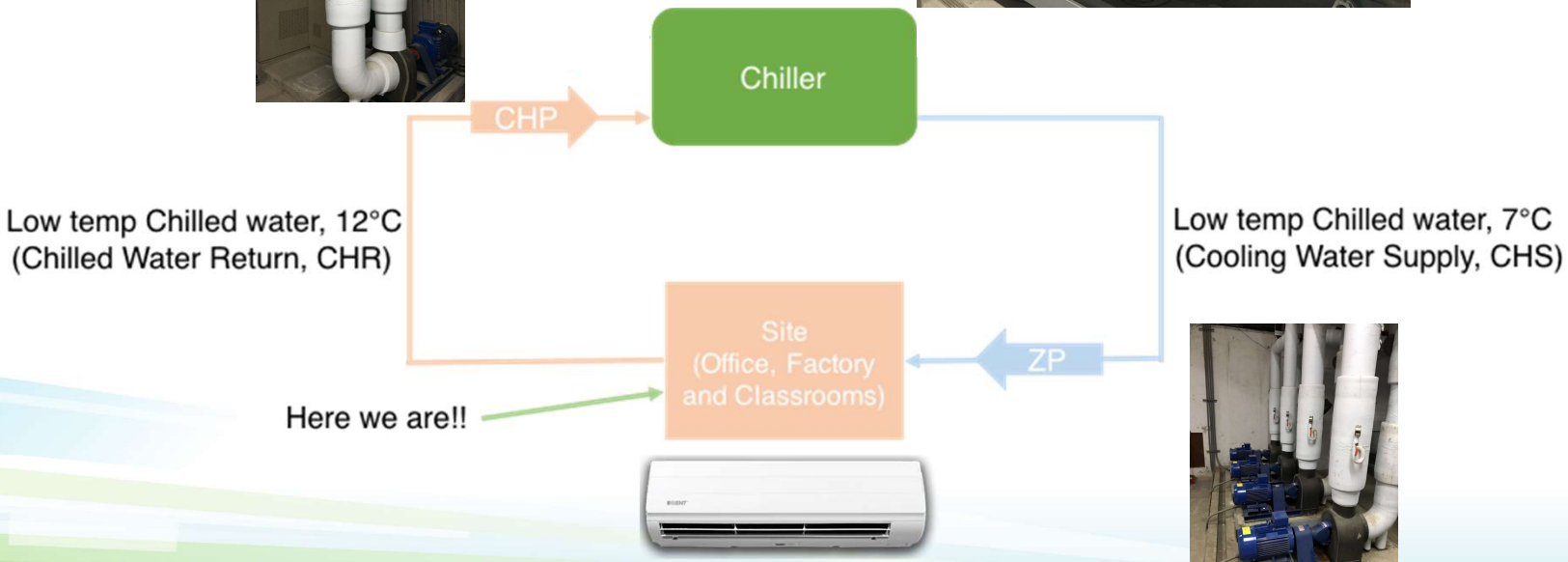
With IoT, predictive modules can be more impactful

Domain Base Knowledge (Ops & Weather)

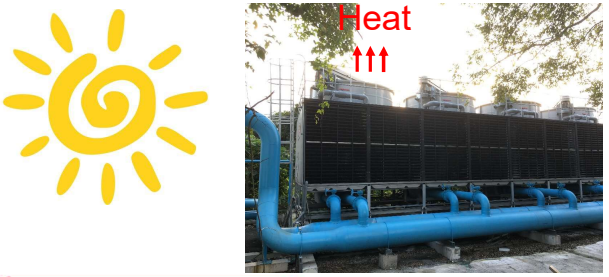
The very first step of building a Predictive Module, get to know who is the target by gaining knowledge.

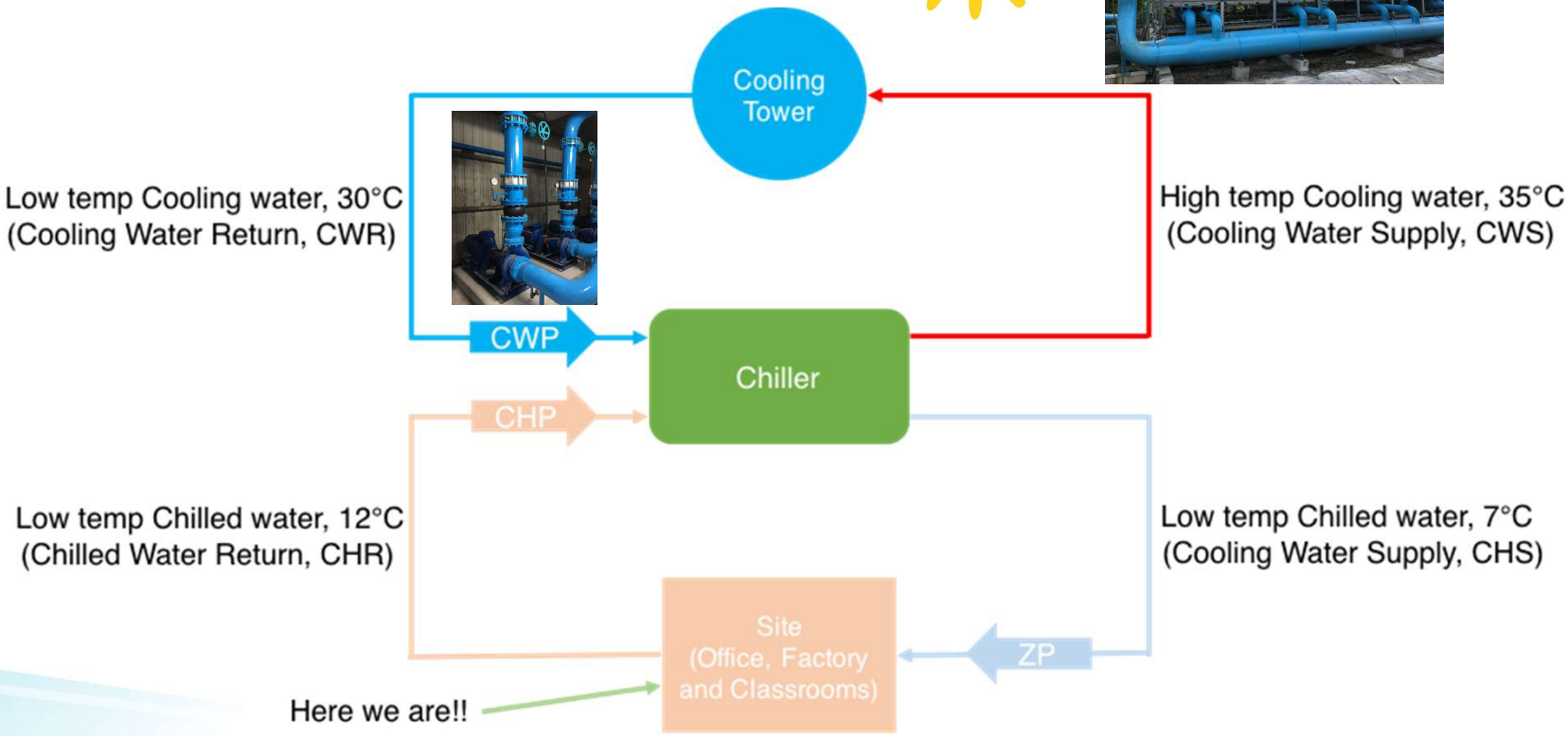
And, why chillers?

Chiller Plant Structure



Chiller Plant Structure

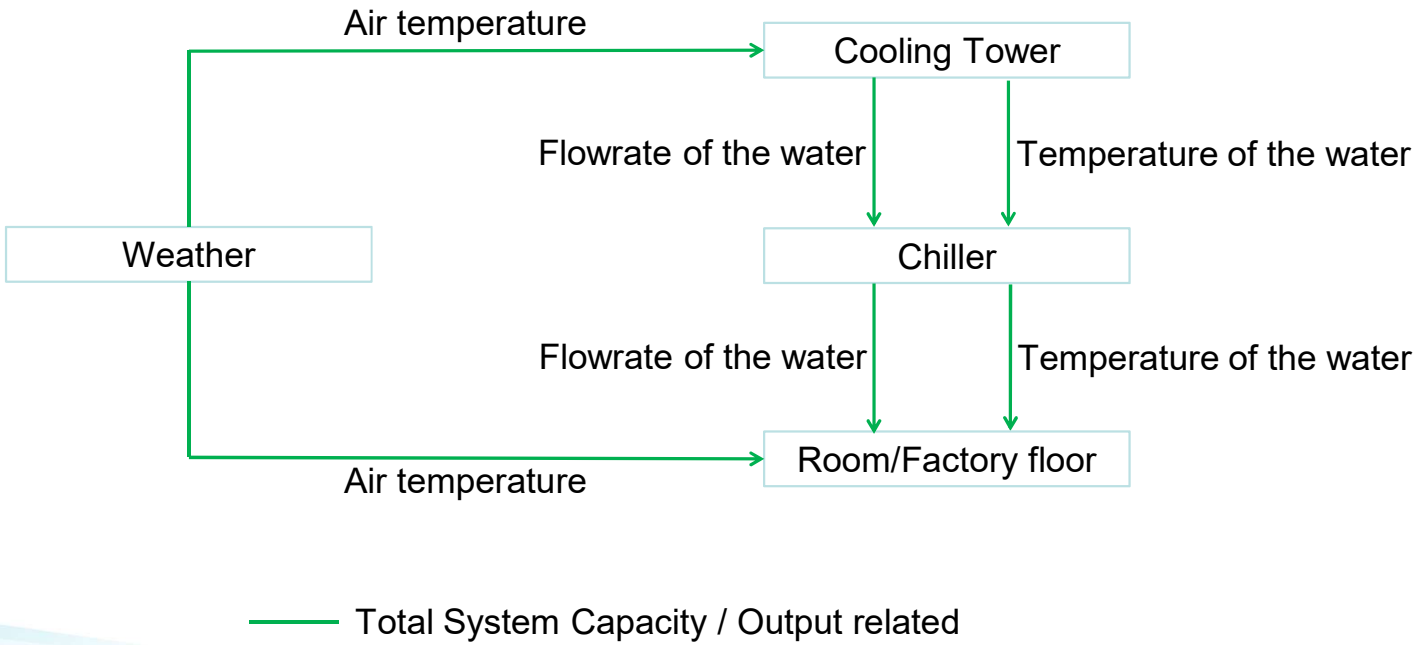




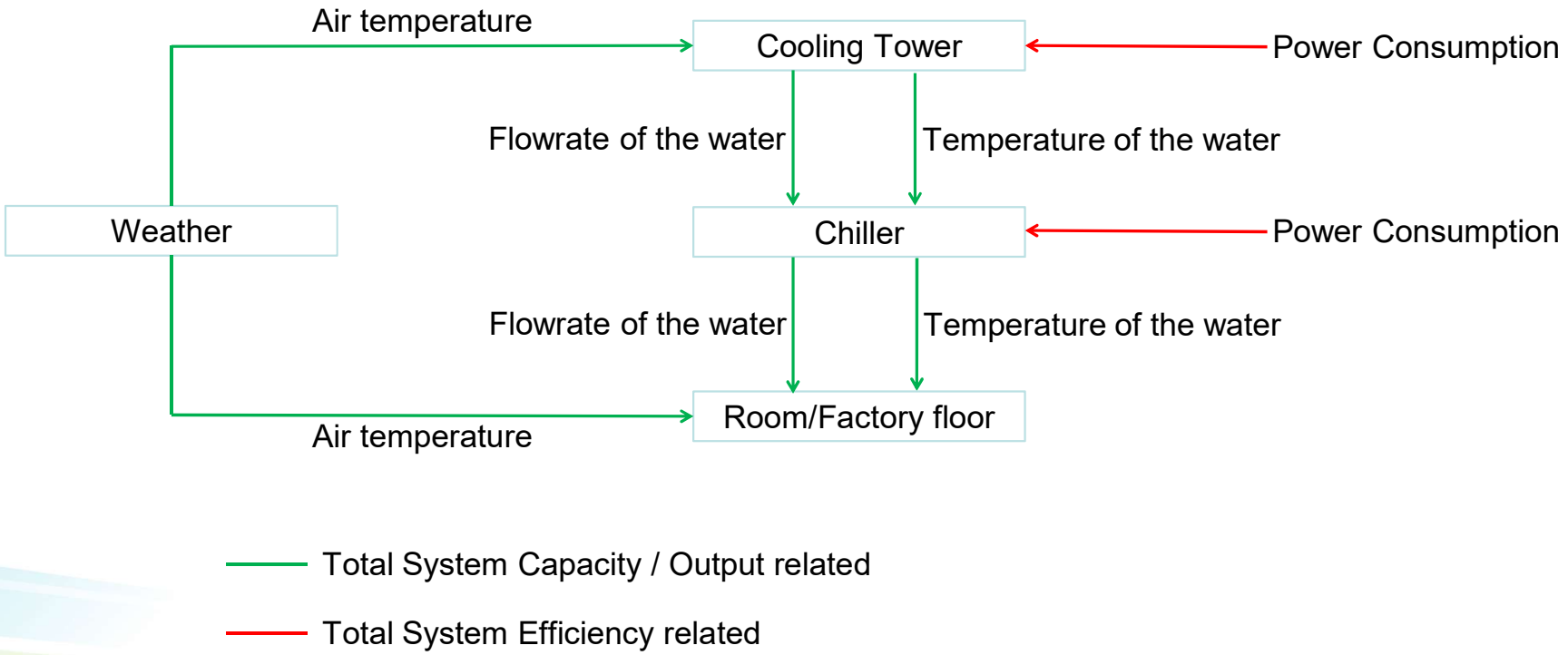
Datasets provided

Data Sets for Chiller	- Power consumption * 1 - Flowrate * 2 - Temperature * 4 - Logs * 1
Data Sets for Cooling Tower	- Power consumption * 1
Data Sets for Pump	- Power consumption * 1

Systems Interactions

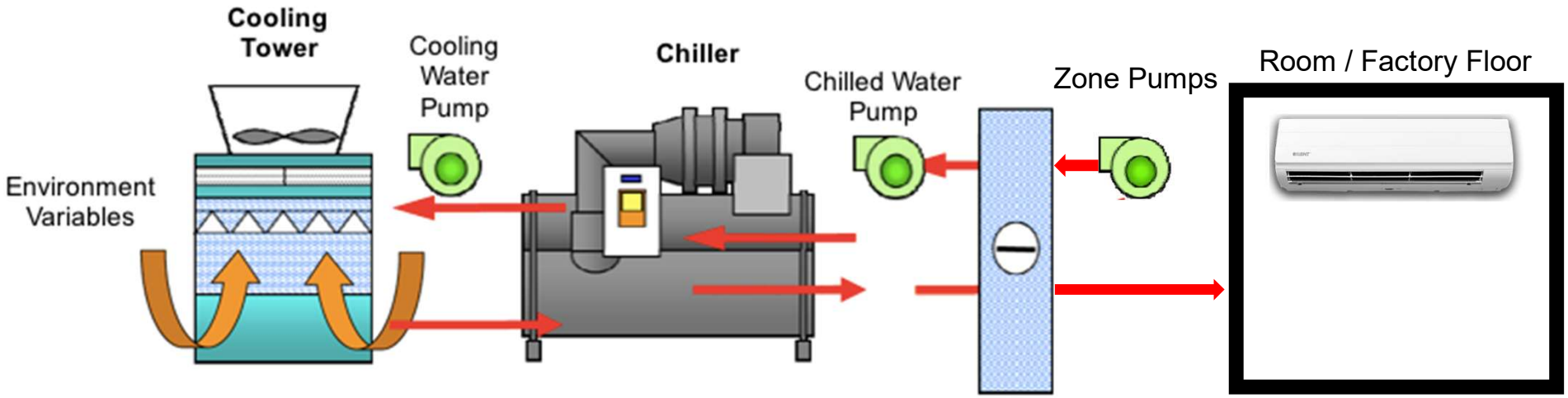


Systems Interactions

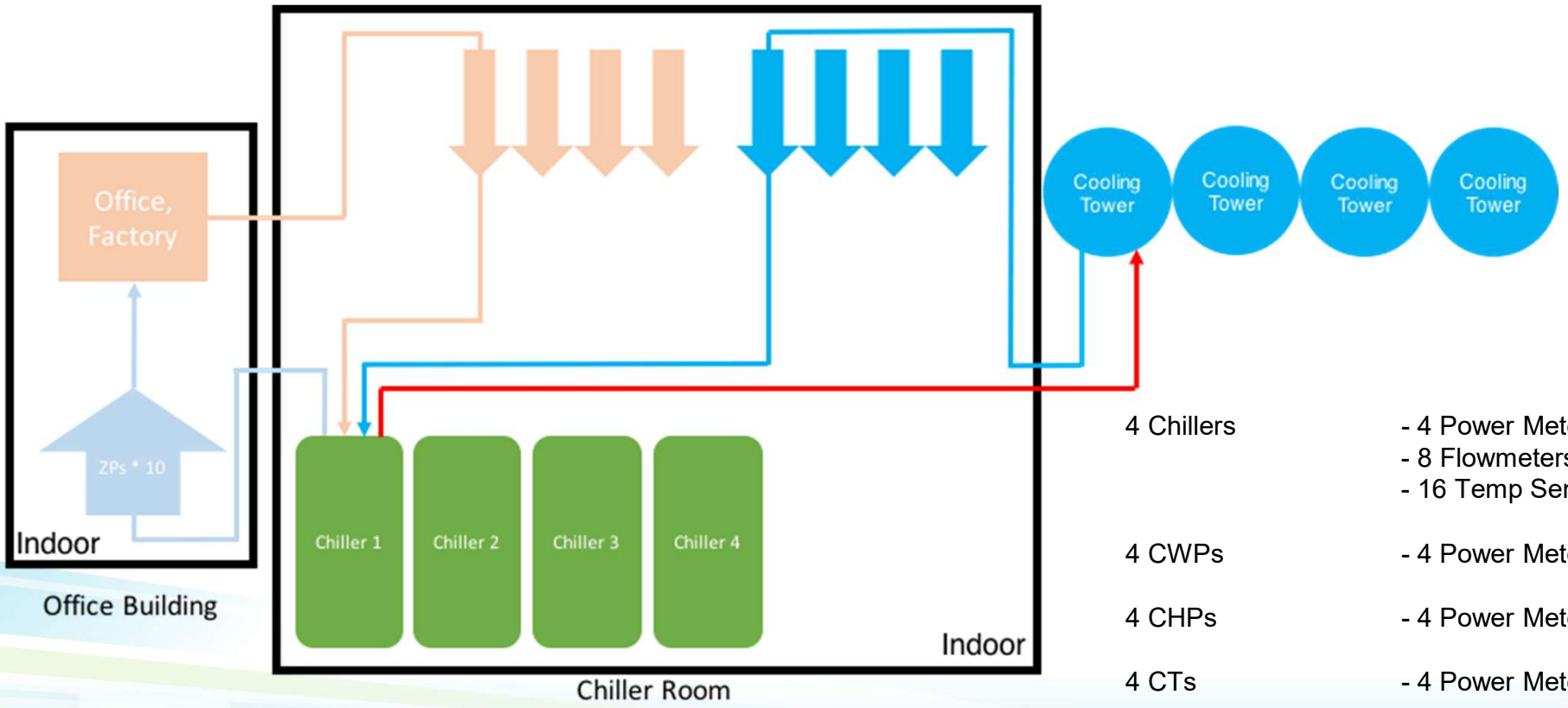


Optimizing Efficiency (Eff)

Eff of **Cooling Tower** + Eff of **C/T Pump** + Eff of **Chiller** + Eff of **Chiller Pump** = Total Efficiency?



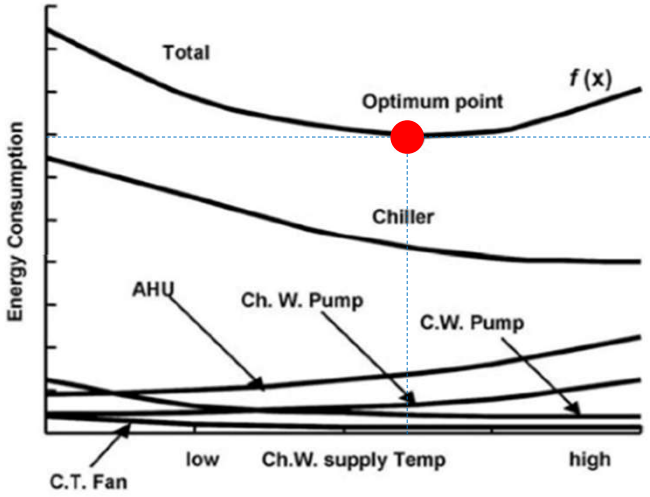
Actual Environment



4 Chillers	- 4 Power Meters - 8 Flowmeters - 16 Temp Sensors
4 CWPs	- 4 Power Meters
4 CHPs	- 4 Power Meters
4 CTs	- 4 Power Meters

So the Optimization should look like

- Chiller Plant component: Chillers, Chilled Water Pump (CHP), Cooling Water Pump (CWP) and Cooling Tower (CT)
- Chiller Plant related component: Air Handling Unit (AHU)



Tzu-Chi Liu, Monitoring and Operation Suggestion for Chiller Plant in High-tech Industry, ITRI, 2011

Lowest Power Consumption
with adequate chilled water output

Finding Optimum Point across

- 4 Chillers
- 4 CHPs
- 4 CWPs
- 4 CTs
- 10 ZPs

Even more to consider…

- Before Chiller starts, the cooling water pump, chilled water pump and cooling tower should start first, or chillers will trip.

- After chiller stops need to left 5 minutes to make refrigerant settle then turn off other components one by one, if not, there will be alarms.

- Should keep chillers scheduled on and off, let chillers take turns and get to know in which scenario there should be two chillers working simultaneously.
  Else the people in office or machines in factory will feel hot.

Sensors (Data Sources)

Getting to know what is the target and what to calculate, now I am trying to collect the numbers by sensors

Power Meters

- Measure on-site power consumption of
  - Chillers
  - Cooling Water Pumps
  - Chilled Water Pumps
  - Cooling Towers
  - Zone Pumps

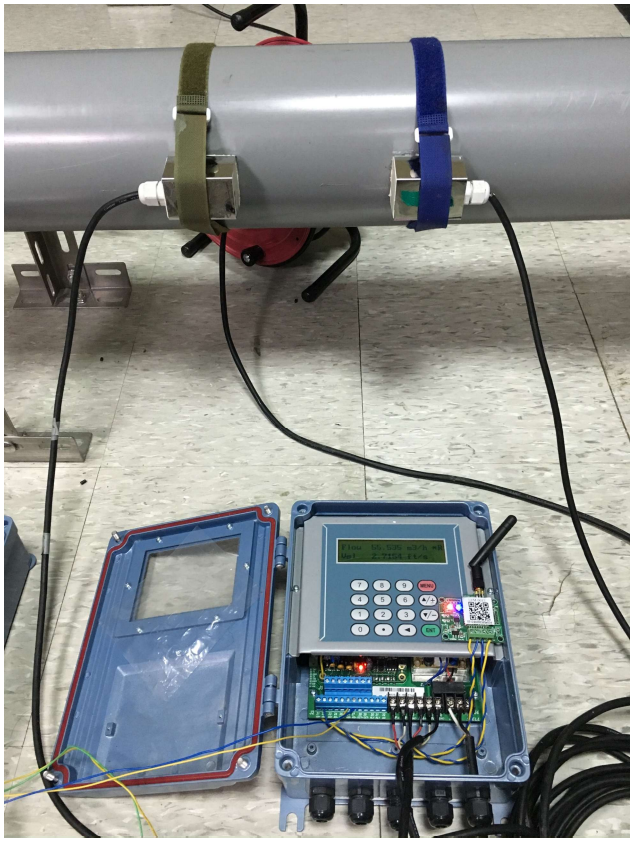
- Wireless Network supported for data retrieving.

Flow Meters

- Measure on-site flowrate data of
  - Evaporator flow (CHS & CHR)
  - Condenser flow (CWS & CWR)

- Set included two ultrasonic detector (upstream and down stream) and flowmeter

- Wireless Network supported for data retrieve, combined with MODBUS protocol and RS485 port.

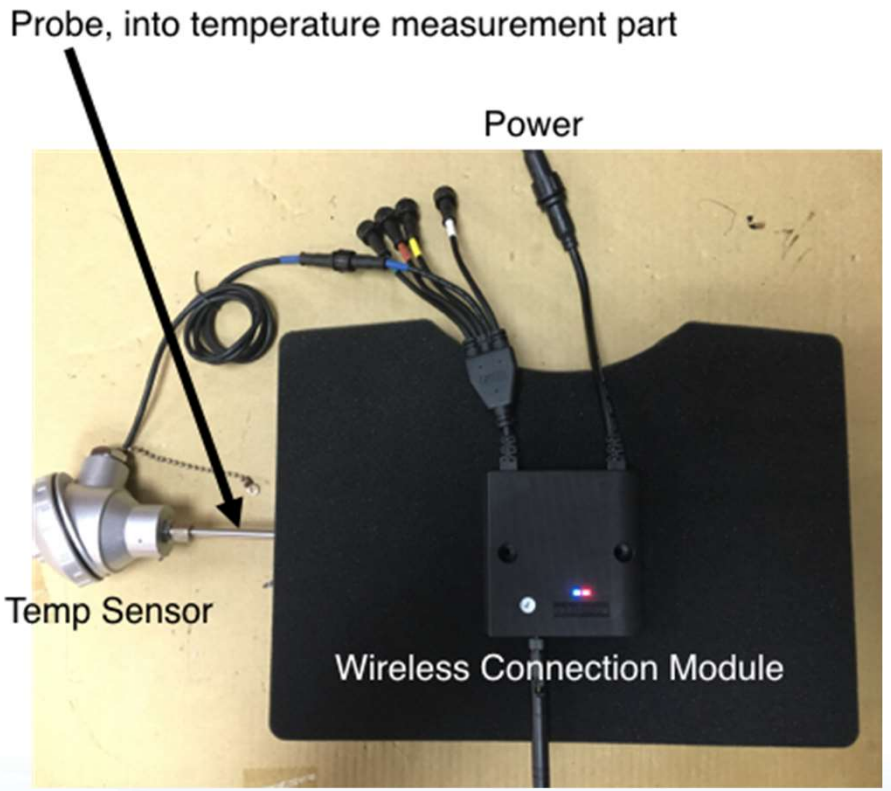


Temp Sensors

- Measure on-site temperature
  - Chilled Water Supply temperature
  - Chilled Water Return temperature
  - Cooling Water Supply temperature
  - Cooling Water Return temperature

- Set included Temp Sensor, probe and Wireless Connection Module

- A Module can support 1 to 5 sensors



Programmable Logic Controller(PLC)

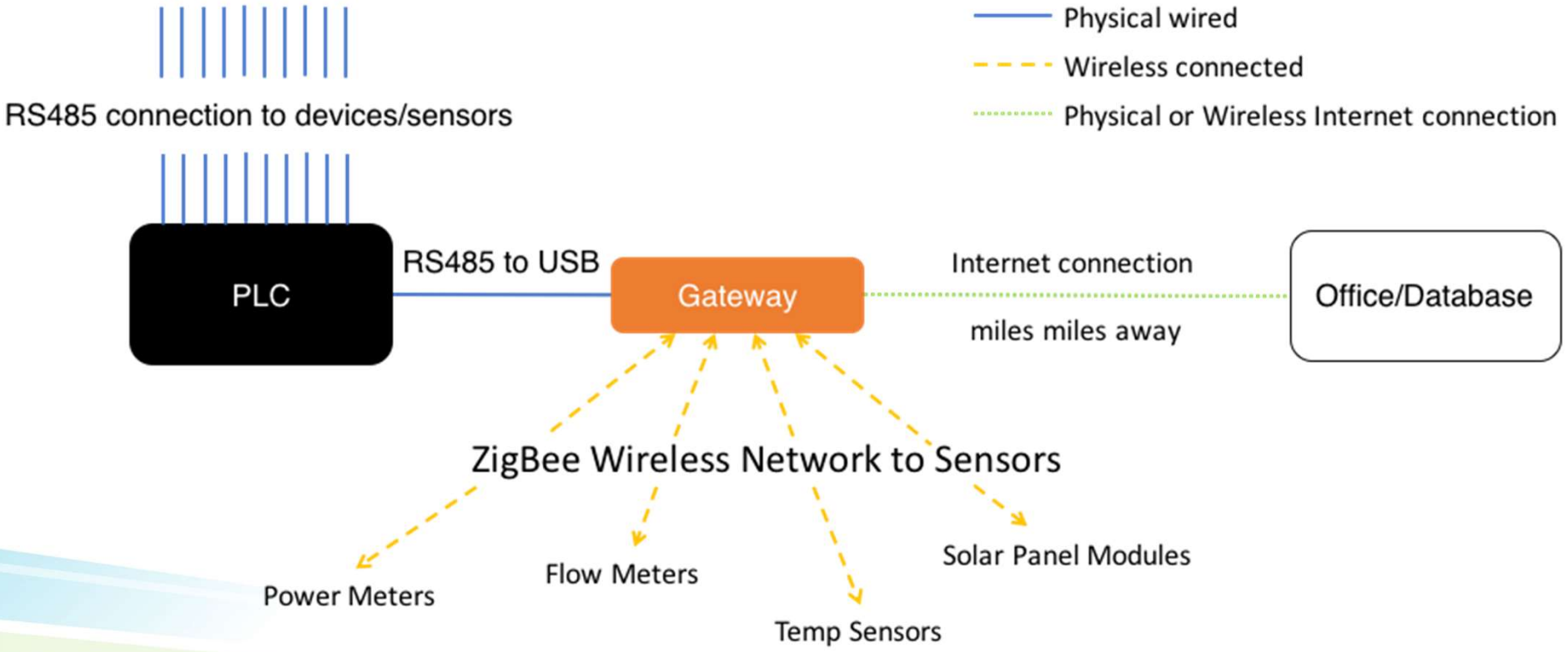
- Connected to devices via wires to both COLLECT and CONTROL

- Collection
  - Monitors equipment status (on/off)
  - Monitors equipment running percentage

- Control
  - Controls equipment status
  - Adjusts equipment running parameters

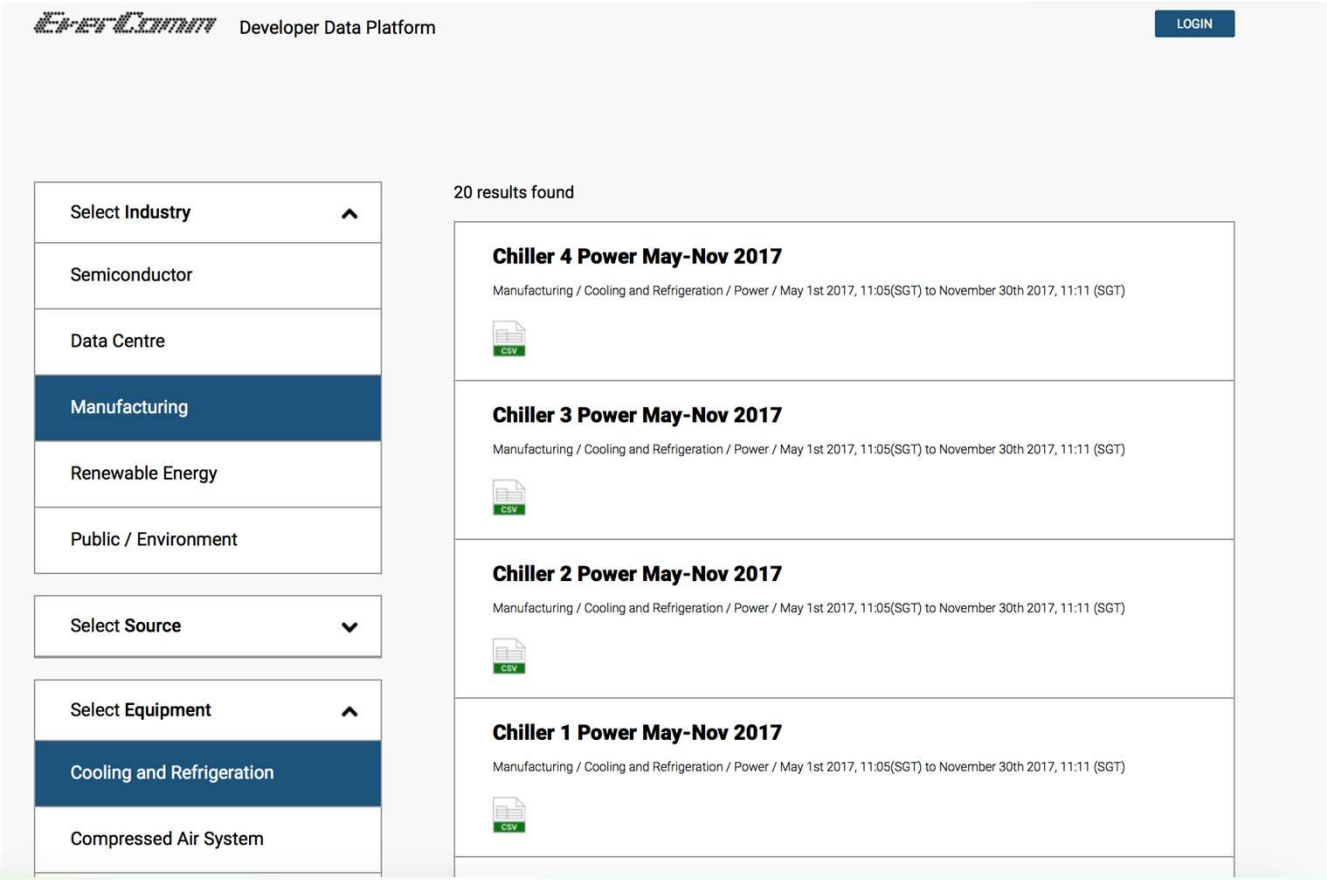
- With RS485 protocol and Internet connection, send data back directly to database in server from site.

The IoT structure for collecting data



The User Interface for you all

- Industry: Manufacturing
- Equipment:
  Cooling and Refrigeration
- Don’t select sources
- Filter by Data Type/Date



Data Columns - Power Meter Data (pm)

Column	Detail
ts	time stamp, time when this row collected into database
gatewayId	The device ID which used to collect data from site
LinkQuality	ZigBee Wireless Network signal strength, range from 0 - 250
ieee	The sensor module ID which used to recognition
ch_Watt	3 phases channel power consumption, total will be whole consumption measured in Watt(W)
totalPositiveWattHour	Accumulated positive power consumption in Watt(W)
totalNegativeWattHour	Accumulated negative power consumption in Watt(W)
ch_Current	The current measured in each channel in Amper(I)
ch_Voltage	The voltage measured in each channel in Volt(V)
ch_PowerFactor	The Power Factor parameter measured in each channel to get real power consumption
voltage_ _	The voltage gap between two channels
Ch_Hz	The alternative current frequency in each channel
i_THD	The current Total Harmonic Distortion in each channel in percentage(%)
v_THD	The voltage Total Harmonic Distortion in each channel in percentage(%)
tm	Database backup time management

Data Columns - Flow Meter Data (ultrasonicFlow)

Column	Detail
ts	time stamp, time when this row collected into database
gatewayId	The device ID which used to collect data from site
LinkQuality	ZigBee Wireless Network signal strength, range from 0 - 250
ieee	The sensor module ID which used to recognition
flowRate	The exact flow rate collected at this time stamp in liter-per-minute(lpm)
flowSpeed	The exact flow speed collected at this time stamp
totalFlowrate	The accumulated flowrate in lpm
positiveTotalFlow	The accumulated flowrate which only adds positive flow
positiveTotalFlowDecimal	The accumulated flowrate in decimal
quality	The ultrasonic sensor collection rate quality range in 0 - 99
upstream	The ultrasonic upstream sensor signal strength range in 0 - 99
downstream	The ultrasonic downstream sensor signal strengthrange in 0 - 99
inletTemp	If temperature module is added, the inlet side temperature in ℃
outletTemp	If temperature module is added, the inlet side temperature in ℃
degree	Setup in flowmeters
unit	Setup in flowmeters
tm	Database backup time management

Data Columns - Temp Data (ain)

Column	Detail
ts	time stamp, time when this row collected into database
gatewayId	The device ID which used to collect data from site
LinkQuality	ZigBee Wireless Network signal strength, range from 0 - 250
ieee	The sensor module ID which used to recognition
ain_	10-bit data collected from probe range from 0-1024
voltage_	Voltage data collect from probe range from 0.66 to 3.3 Volt(V)
value_	The data which converted into temperature value 1: chilled water supply temperature (cold) value 2: chilled water return temperature (warm) value 3: cooling water supply temperature (hot) value 4: cooling water return temperature (cool)
tm	Database backup time management

Data Columns – Error Logs

A2 | 8/8/2017 12:05:10 PM

	A	B	C	D	E
1	Start	End	Equipment ID	Error Type	Status
2	05:10.0	13:10.0	ch1	TRIP	Historical
3	56:10.0	04:10.0	ch1	TRIP	Historical
4	38:10.0	14:10.0	ch2	TRIP	Historical
5	19:10.0	39:10.0	ch2	TRIP	Historical
6	53:10.0	04:10.0	ch2	TRIP	Historical
7	14:10.0	44:10.0	ch3	TRIP	Historical
8	47:10.0	14:10.0	ch3	TRIP	Historical
9	34:10.0	39:10.0	ch3	TRIP	Historical
10	40:10.0	41:10.0	ch3	TRIP	Historical
11	50:10.0	00:10.0	ch3	TRIP	Historical
12	09:10.0	39:10.0	ch3	TRIP	Historical
13	40:10.0	28:10.0	ch3	TRIP	Historical
14	41:10.0	06:10.0	ch3	TRIP	Historical
15	15:10.0	42:10.0	ch3	TRIP	Historical
16	24:10.0	40:10.0	ct1	TRIP	Historical
17	24:10.0	40:10.0	ct3	TRIP	Historical
18	24:10.0	40:10.0	ct4	TRIP	Historical
19	05:03.0	14:03.0	ch1	FLOW SWITCH	Historical
20	56:03.0	04:03.0	ch1	FLOW SWITCH	Historical
21	35:04.0	46:03.0	ch1	FLOW SWITCH	Historical
22	51:03.0	52:03.0	ch1	FLOW SWITCH	Historical
23	57:03.0	27:03.0	ch1	FLOW SWITCH	Historical
24	35:04.0	46:03.0	ch1	MS LOW PRESSUR	Historical
25	51:03.0	52:03.0	ch1	MS LOW PRESSUR	Historical
26	57:03.0	27:03.0	ch1	MS LOW PRESSUR	Historical
27	05:03.0	14:03.0	ch1	MS COMPRESSOR	Historical

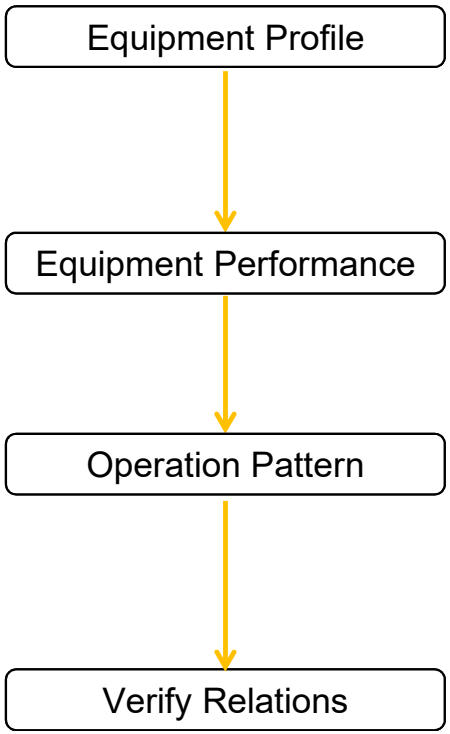
Name	Date modified	Type	Size
Equipment Error Log_2017-07-01_2017-07-31	12/14/2017 9:17 A...	Microsoft Excel Co...	7 KB
Equipment Error Log_2017-08-01_2017-08-31	12/14/2017 9:17 A...	Microsoft Excel Co...	6 KB
Equipment Error Log_2017-09-01_2017-09-30	12/14/2017 9:17 A...	Microsoft Excel Co...	1 KB
Equipment Error Log_2017-10-01_2017-10-31	12/14/2017 9:18 A...	Microsoft Excel Co...	1 KB

Data Analysis

I am a chiller expert now, I know how to judge if this chiller is running well. I can get data back from site. What's next?

Tools that can be used in dealing with Data

Flow before Optimization



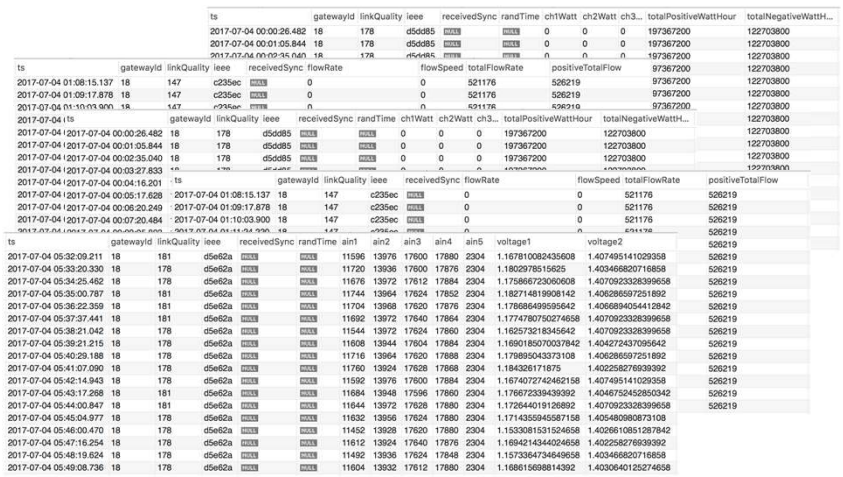
Observe & Understanding Fault Patterns

Pre-works before dealing with Data

```
SELECT date_format(ts, '%Y-%m-%d %H:%i') as ts, (ch1Watt+ch2Watt+ch3Watt)/1000 as kW FROM
WHERE ieee like 'd5e87f'
AND ts>'2017-12-08 00:00:00' AND ts<'2017-12-15 00:00:00';
```

- Eliminate diversity of the data downloaded
- Name or tag data downloaded as a system
- Try different folders to store different phase of data

Dealing with Data



ts	gatewayId	linkQuality	ieee	receivedSync	randTime	ch1Watt	ch2Watt	ch3...	totalPositiveWattHour	totalNegativeWattH...
2017-07-04 00:00:26.482	18	178	d5dd85	NULL	NULL	0	0	0	197367200	122703800
2017-07-04 00:01:05.844	18	178	d5dd85	NULL	NULL	0	0	0	197367200	122703800
2017-07-04 00:02:35.040	18	178	d5dd85	NULL	NULL	0	0	0	197367200	122703800

ts	gatewayId	linkQuality	ieee	receivedSync	flowRate	flowSpeed	totalFlowRate	positiveTotalFlow	97367200	122703800
2017-07-04 01:08:15.137	18	147	c235ec	NULL	0	0	521176	526219	97367200	122703800
2017-07-04 01:09:17.878	18	147	c235ec	NULL	0	0	521176	526219	97367200	122703800

ts	gatewayId	linkQuality	ieee	receivedSync	randTime	ch1Watt	ch2Watt	ch3...	totalPositiveWattHour	totalNegativeWattH...
2017-07-04 00:00:26.482	18	178	d5dd85	NULL	NULL	0	0	0	197367200	122703800
2017-07-04 00:01:05.844	18	178	d5dd85	NULL	NULL	0	0	0	197367200	122703800
2017-07-04 00:02:35.040	18	178	d5dd85	NULL	NULL	0	0	0	197367200	122703800

ts	gatewayId	linkQuality	ieee	receivedSync	flowRate	flowSpeed	totalFlowRate	positiveTotalFlow
2017-07-04 00:04:16.201								
2017-07-04 00:05:17.628	2017-07-04 01:08:15.137	18	147	c235ec	NULL	0	0	521176	526219
2017-07-04 00:06:20.249	2017-07-04 01:09:17.878	18	147	c235ec	NULL	0	0	521176	526219
2017-07-04 00:07:20.484	2017-07-04 01:10:03.900	18	147	c235ec	NULL	0	0	521176	526219

ts	gatewayId	linkQuality	ieee	receivedSync	randTime	ain1	ain2	ain3	ain4	ain5	voltage1	voltage2	526219
2017-07-04 05:32:09.211	18	181	d5e62a	NULL	NULL	11596	13976	17600	17880	2304	1.167810082435608	1.407495141029358	526219
2017-07-04 05:33:20.330	18	178	d5e62a	NULL	NULL	11720	13936	17600	17876	2304	1.1802978515625	1.403466820716858	526219
2017-07-04 05:34:25.462	18	178	d5e62a	NULL	NULL	11676	13972	17612	17884	2304	1.175866723060608	1.4070923328399658	526219
2017-07-04 05:35:00.787	18	181	d5e62a	NULL	NULL	11744	13964	17624	17852	2304	1.182714819908142	1.406286597251892	526219
2017-07-04 05:36:22.359	18	181	d5e62a	NULL	NULL	11704	13968	17620	17876	2304	1.178686499595642	1.406689405412842	526219
2017-07-04 05:37:37.441	18	181	d5e62a	NULL	NULL	11692	13972	17640	17864	2304	1.1774780750274658	1.4070923328399658	526219
2017-07-04 05:38:21.042	18	178	d5e62a	NULL	NULL	11544	13972	17624	17860	2304	1.162573218345642	1.4070923328399658	526219
2017-07-04 05:39:21.215	18	178	d5e62a	NULL	NULL	11608	13944	17604	17884	2304	1.1690185070037842	1.4042724370956642	526219
2017-07-04 05:40:29.188	18	178	d5e62a	NULL	NULL	11716	13964	17620	17888	2304	1.1798950433731108	1.406286597251892	526219
2017-07-04 05:41:07.090	18	178	d5e62a	NULL	NULL	11760	13924	17628	17868	2304	1.184326171875	1.402258276939392	526219
2017-07-04 05:42:14.943	18	178	d5e62a	NULL	NULL	11592	13976	17600	17884	2304	1.1674072742462158	1.407495141029358	526219
2017-07-04 05:43:17.268	18	181	d5e62a	NULL	NULL	11684	13948	17596	17860	2304	1.176672339439392	1.4046752452850342	526219
2017-07-04 05:44:00.847	18	181	d5e62a	NULL	NULL	11644	13972	17628	17880	2304	1.172644019126892	1.4070923328399658	526219
2017-07-04 05:45:04.977	18	178	d5e62a	NULL	NULL	11632	13956	17624	17880	2304	1.1714355945587158	1.405480980873108	
2017-07-04 05:46:00.470	18	178	d5e62a	NULL	NULL	11452	13928	17620	17880	2304	1.1533081531524658	1.4026610851287842	
2017-07-04 05:47:16.254	18	178	d5e62a	NULL	NULL	11612	13924	17640	17876	2304	1.1694214344024658	1.402258276939392	
2017-07-04 05:48:19.624	18	178	d5e62a	NULL	NULL	11492	13936	17624	17848	2304	1.1573364734649658	1.403466820716858	
2017-07-04 05:48:08.736	18	178	d5e62a	NULL	NULL	11604	13932	17612	17880	2304	1.168615698814392	1.4030640125274658	

Processed

2017/07/01 5:59 AM	221.23963928	8.6474603634	7.205504724	46.04	200.99104309	26.420897814	27.724000362
2017/07/01 6:01 AM	222.4932251	8.7435913715	7.1093752963	52.924	200.87472534	26.36749205	27.830811891
2017/07/01 6:02 AM	224.86712646	8.7329092703	7.205504724	46.659	201.25257874	26.463623058	27.82013137
2017/07/01 6:03 AM	229.98327637	8.7222287496	7.205504724	45.543	201.59873962	26.399536773	27.713319842
2017/07/01 6:04 AM	224.42138672	8.7329092703	7.1414184389	53.632	201.49629211	26.36749205	27.766725606
2017/07/01 6:05 AM	218.04605103	8.7435913715	7.205504724	51.336	201.05032349	26.388856252	27.777406127
2017/07/01 6:06 AM	218.52928162	8.7115482289	7.120055817	51.884	200.8598938	26.442262016	28.023070747
2017/07/01 6:07 AM	217.57673645	8.7222287496	7.2482299677	44.884	200.90602112	26.399536773	27.958984461
2017/07/01 6:08 AM	221.34805298	8.7329092703	7.2161868252	45.676	201.30064392	26.420897814	27.948303941
2017/07/01 6:09 AM	220.24307251	8.7222287496	7.2268673459	47.266	201.13774109	26.431581496	27.873537135
2017/07/01 6:10 AM	225.44113159	8.7222287496	7.2375478666	51.954	201.1302948	26.48498726	27.659914077
2017/07/01 6:11 AM	224.28771973	8.7329092703	7.1307363378	52.693	200.64904785	26.431581496	27.884217656
2017/07/01 6:12 AM	218.8163147	8.7008661278	7.205504724	47.32	200.88652039	26.399536773	27.905578697
2017/07/01 6:15 AM	220.61029053	8.7542718922	7.1414184389	51.305	200.53648376	26.506348301	27.991029184
2017/07/01 6:16 AM	224.71711731	8.6260977415	7.0880126745	51.344	200.24751282	26.517028822	28.108521234
2017/07/01 6:17 AM	217.63728333	8.6474603634	7.1093752963	46.463	200.43734741	26.48498726	28.129882275
2017/07/01 6:18 AM	220.10258484	8.6901856071	7.2268673459	46.182	200.29498291	26.495667781	28.033754428
2017/07/01 6:19 AM	221.25544739	8.6047367001	7.2375478666	48.46	200.11141968	26.48498726	27.980348664
2017/07/01 6:20 AM	226.68191528	8.7649539933	7.205504724	52.563	199.99253845	26.442262016	28.05511547
2017/07/01 6:21 AM	220.15393066	8.6154172208	7.1307363378	49.435	200.01701355	26.634520872	28.119201755
2017/07/01 6:22 AM	225.90229797	8.7329092703	7.1627810607	48.417	199.74763489	26.570434587	28.033754428
2017/07/01 6:23 AM	223.26760864	8.6474603634	7.1948242033	51.745	199.87825012	26.591798789	28.033754428
2017/07/01 6:24 AM	225.83695984	8.6367798426	7.1093752963	53.416	199.9250946	26.591798789	28.119201755
2017/07/01 6:25 AM	223.30918884	8.7222287496	7.2268673459	45.786	200.05644226	26.634520872	28.119201755
2017/07/01 6:26 AM	221.39231873	8.6260977415	7.1307363378	49.871	200.57894897	26.634520872	28.258058007
2017/07/01 6:27 AM	220.43151855	8.7329092703	7.1093752963	50.883	200.26463318	26.709290838	28.236693804
2017/07/01 6:29 AM	218.33648682	8.6367798426	7.2375478666	48.334	200.64251709	26.762696603	28.023070747
2017/07/01 6:30 AM	224.73719788	8.6154172208	7.120055817	52.997	200.18025208	26.698610318	28.129882275
2017/07/01 6:31 AM	220.68484497	8.6367798426	7.0880126745	51.421	200.49868774	26.709290838	28.108521234
2017/07/01 6:32 AM	218.28413391	8.7542718922	7.0986931952	48.574	200.34925842	26.7413324	28.108521234
2017/07/01 6:33 AM	221.93569946	8.6367798426	7.2375478666	50.577	200.49325562	26.719971359	28.06579599
2017/07/01 6:34 AM	224.56661987	8.6260977415	7.1520989596	52.912	200.5226593	26.698610318	28.215332763
2017/07/01 6:35 AM	218.91299438	8.6474603634	7.1093752963	46.726	200.16188049	26.709290838	28.236693804
2017/07/01 6:36 AM	223.95123291	8.7222287496	7.2375478666	48.594	200.18379211	26.73065188	28.151246478

Start with filter data

ts	gatewayId	linkQuality	ieee	receivedSync	flowRate	flowSpeed	totalFlowRat	positiveTotal	positiveTotal
7/4/17 1:59 PM	18	115	c2369e	NULL	208.570877	1.79466116	269171	269375	1049624445
7/4/17 2:00 PM	18	115	c2369e	NULL	203.962326	1.75500655	269174	269378	1060503550
7/4/17 2:01 PM	18	115	c2369e	NULL	208.697433	1.79575002	269178	269382	1043070846
7/4/17 2:02 PM	18	115	c2369e	NULL	205.861267	1.77134609	269181	269385	1057947452
7/4/17 2:03 PM	18	115	c2369e	NULL	208.034683	1.79004741	269184	269389	1012203444
7/4/17 2:05 PM	18	115	c2369e	NULL	204.3582	1.75841296	269191	269395	1062993790
7/4/17 2:06 PM	18	115	c2369e	NULL	204.407288	1.7588352	269195	269399	1048969077
7/4/17 2:07 PM	18	115	c2369e	NULL	203.680664	1.75258291	269198	269402	1059979062
7/4/17 2:08 PM	18	115	c2369e	NULL	206.077255	1.77320457	269202	269406	1036845044
7/4/17 2:09 PM	18	115	c2369e	NULL	205.321655	1.76670301	269205	269409	1057816509
7/4/17 2:10 PM	18	115	c2369e	NULL	208.091019	1.79053211	269208	269412	1064435583
7/4/17 2:11 PM	18	115	c2369e	NULL	210.750504	1.81341577	269212	269416	1052573694
7/4/17 2:12 PM	18	115	c2369e	NULL	206.26712	1.77483821	269215	269419	1062010743
7/4/17 2:13 PM	18	115	c2369e	NULL	203.036606	1.74704099	269219	269423	1046740991
7/4/17 2:14 PM	18	115	c2369e	NULL	204.312836	1.75802243	269222	269426	1059454772
7/4/17 2:15 PM	18	115	c2369e	NULL	207.30719	1.78378761	269226	269430	1033240503
7/4/17 2:16 PM	18	115	c2369e	NULL	204.656448	1.76097918	269229	269433	1056898998
7/4/17 2:18 PM	18	115	c2369e	NULL	203.872482	1.7542336	269236	269440	1052901374
7/4/17 2:19 PM	18	115	c2369e	NULL	209.023468	1.79855537	269239	269443	1061683188
7/4/17 2:20 PM	18	113	c2369e	NULL	202.387711	1.74145758	269243	269447	1045954429
7/4/17 2:21 PM	18	115	c2369e	NULL	201.441315	1.73331416	269246	269450	1059585911
7/4/17 2:22 PM	18	115	c2369e	NULL	200.787399	1.72768772	269250	269454	1034682292
7/4/17 2:23 PM	18	115	c2369e	NULL	210.214508	1.8088038	269253	269457	1057357814
7/4/17 2:24 PM	18	115	c2369e	NULL	205.909958	1.77176499	269256	269460	1064763197
7/4/17 2:25 PM	18	115	c2369e	NULL	206.026413	1.77276695	269260	269464	1053687733
7/4/17 2:26 PM	18	115	c2369e	NULL	204.576294	1.76028931	269263	269467	1062797246
7/4/17 2:27 PM	18	115	c2369e	NULL	208.771713	1.79638934	269267	269471	1049755638
7/4/17 2:28 PM	18	115	c2369e	NULL	205.244965	1.76604307	269270	269474	1060831094
7/4/17 2:29 PM	18	115	c2369e	NULL	210.675247	1.81276834	269274	269478	1042939839

ts	conflowrate
04/07/2017 13:59	208.570877
04/07/2017 14:00	203.962326
04/07/2017 14:01	208.697433
04/07/2017 14:02	205.861267
04/07/2017 14:03	208.034683
04/07/2017 14:05	204.3582
04/07/2017 14:06	204.407288
04/07/2017 14:07	203.680664
04/07/2017 14:08	206.077255
04/07/2017 14:09	205.321655
04/07/2017 14:10	208.091019
04/07/2017 14:11	210.750504
04/07/2017 14:12	206.26712
04/07/2017 14:13	203.036606
04/07/2017 14:14	204.312836
04/07/2017 14:15	207.30719
04/07/2017 14:16	204.656448
04/07/2017 14:18	203.872482
04/07/2017 14:19	209.023468
04/07/2017 14:20	202.387711
04/07/2017 14:21	201.441315
04/07/2017 14:22	200.787399
04/07/2017 14:23	210.214508
04/07/2017 14:24	205.909958
04/07/2017 14:25	206.026413
04/07/2017 14:26	204.576294
04/07/2017 14:27	208.771713
04/07/2017 14:28	205.244965
04/07/2017 14:29	210.675247

Combining all the filtered data parts

22/07/2017 12:28	73.859
22/07/2017 12:29	77.067
22/07/2017 12:31	76.468
22/07/2017 12:32	74.715
22/07/2017 12:33	74.68
22/07/2017 12:34	75.466
22/07/2017 12:35	74.697
22/07/2017 12:36	79.913
22/07/2017 12:37	83.448
22/07/2017 12:38	80.989
22/07/2017 12:39	74.815
22/07/2017 12:40	74.755
22/07/2017 12:41	77.085
22/07/2017 12:42	74.626
22/07/2017 12:43	82.564
22/07/2017 12:44	85.159
22/07/2017 12:45	75.298
22/07/2017 12:46	75.096
22/07/2017 12:47	74.859
22/07/2017 12:48	76.957
22/07/2017 12:50	74.612
22/07/2017 12:51	77.808
22/07/2017 12:52	83.97
22/07/2017 12:53	74.414
22/07/2017 12:55	74.108
22/07/2017 12:56	75.731
22/07/2017 12:57	74.222

7/19/17 10:29 AM	220.218277
7/19/17 10:30 AM	217.47226
7/19/17 10:31 AM	222.658417
7/19/17 10:32 AM	217.059738
7/19/17 10:33 AM	219.07692
7/19/17 10:34 AM	215.453384
7/19/17 10:35 AM	219.212616
7/19/17 10:36 AM	221.26561
7/19/17 10:37 AM	222.174606
7/19/17 10:38 AM	219.418137
7/19/17 10:39 AM	224.917526
7/19/17 10:40 AM	219.913574
7/19/17 10:41 AM	216.40799
7/19/17 10:42 AM	219.727707
7/19/17 10:43 AM	218.052322
7/19/17 10:44 AM	220.565811
7/19/17 10:45 AM	219.174469
7/19/17 10:46 AM	217.867523
7/19/17 10:47 AM	219.506836
7/19/17 10:48 AM	219.067703
7/19/17 10:49 AM	219.701691
7/19/17 10:50 AM	220.384186
7/19/17 10:51 AM	217.975616
7/19/17 10:52 AM	221.220734
7/19/17 10:53 AM	219.34108
7/19/17 10:54 AM	215.945618
7/19/17 10:55 AM	216.67218
7/19/17 10:56 AM	222.70874

2017/07/01 5:59 AM	221.23963928	8.6474603634	7.205504724	46.04	200.99104309	26.420897814	27.724000362
2017/07/01 6:01 AM	222.4932251	8.7435913715	7.1093752963	52.924	200.87472534	26.36749205	27.830811891
2017/07/01 6:02 AM	224.86712646	8.7329092703	7.205504724	46.659	201.25257874	26.463623058	27.82013137
2017/07/01 6:03 AM	229.98327637	8.7222287496	7.205504724	45.543	201.59873962	26.399536773	27.713319842
2017/07/01 6:04 AM	224.42138672	8.7329092703	7.1414184389	53.632	201.49629211	26.36749205	27.766725606
2017/07/01 6:05 AM	218.04605103	8.7435913715	7.205504724	51.336	201.05032349	26.388856252	27.777406127
2017/07/01 6:06 AM	218.52928162	8.7115482289	7.120055817	51.884	200.8598938	26.442262016	28.023070747
2017/07/01 6:07 AM	217.57673645	8.7222287496	7.2482299677	44.884	200.90602112	26.399536773	27.958984461
2017/07/01 6:08 AM	221.34805298	8.7329092703	7.2161868252	45.676	201.30064392	26.420897814	27.948303941
2017/07/01 6:09 AM	220.24307251	8.7222287496	7.2268673459	47.266	201.13774109	26.431581496	27.873537135
2017/07/01 6:10 AM	225.44113159	8.7222287496	7.2375478666	51.954	201.1302948	26.48498726	27.659914077
2017/07/01 6:11 AM	224.28771973	8.7329092703	7.1307363378	52.693	200.64904785	26.431581496	27.884217656
2017/07/01 6:12 AM	218.8163147	8.7008661278	7.205504724	47.32	200.88652039	26.399536773	27.905578697
2017/07/01 6:15 AM	220.61029053	8.7542718922	7.1414184389	51.305	200.53648376	26.506348301	27.991029184
2017/07/01 6:16 AM	224.71711731	8.6260977415	7.0880126745	51.344	200.24751282	26.517028822	28.108521234
2017/07/01 6:17 AM	217.63728333	8.6474603634	7.1093752963	46.463	200.43734741	26.48498726	28.129882275
2017/07/01 6:18 AM	220.10258484	8.6901856071	7.2268673459	46.182	200.29498291	26.495667781	28.033754428
2017/07/01 6:19 AM	221.25544739	8.6047367001	7.2375478666	48.46	200.11141968	26.48498726	27.980348664
2017/07/01 6:20 AM	226.68191528	8.7649539933	7.205504724	52.563	199.99253845	26.442262016	28.05511547
2017/07/01 6:21 AM	220.15393066	8.6154172208	7.1307363378	49.435	200.01701355	26.634520872	28.119201755
2017/07/01 6:22 AM	225.90229797	8.7329092703	7.1627810607	48.417	199.74763489	26.570434587	28.033754428
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2017/07/01 6:29 AM	218.33648682	8.6367798426	7.2375478666	48.334	200.64251709	26.762696603	28.023070747
2017/07/01 6:30 AM	224.73719788	8.6154172208	7.120055817	52.997	200.18025208	26.698610318	28.129882275
2017/07/01 6:31 AM	220.68484497	8.6367798426	7.0880126745	51.421	200.49868774	26.709290838	28.108521234
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2017/07/01 6:34 AM	224.56661987	8.6260977415	7.1520989596	52.912	200.5226593	26.698610318	28.215332763
2017/07/01 6:35 AM	218.91299438	8.6474603634	7.1093752963	46.726	200.16188049	26.709290838	28.236693804
2017/07/01 6:36 AM	223.95123291	8.7222287496	7.2375478666	48.594	200.18379211	26.73065188	28.151246478

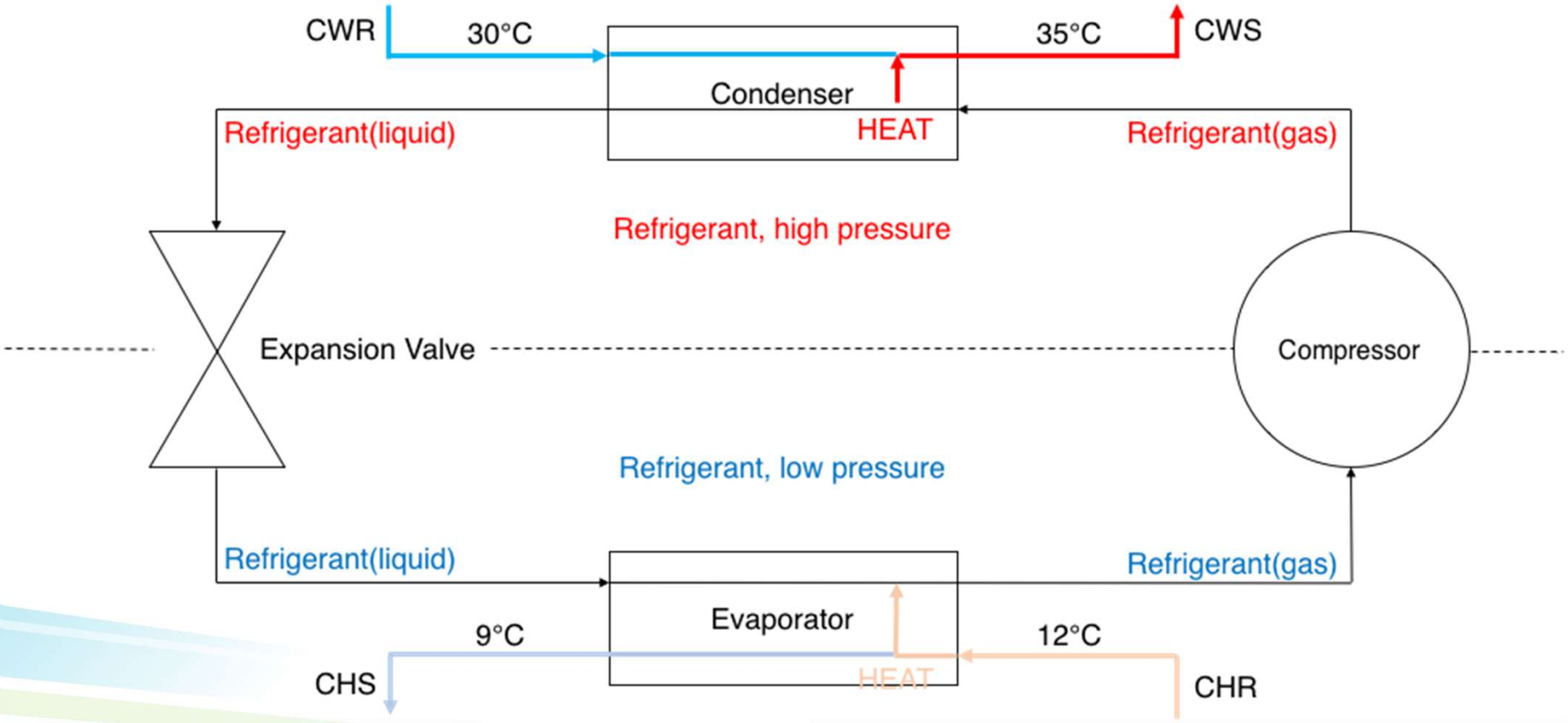
Chillers

- Chiller is the component in the chiller plant where water is chilled then transferred to site to provide Air-conditioner(or AHUs) delivering cold air into offices, factories, class rooms and labs

- Chiller is composed of evaporator, condenser, compressor and pipes.

http://www.johnsoncontrols.com/-/media/jci/be/united-states/hvac-equipment/images/be_l2_chillers.jpg

Chiller cycle within



How to evaluate Chiller performance

- To evaluate how the Chiller is working we can judge by two calculated numbers: Heat Capacity Rate and COP

- Heat Capacity Rate is the amount of how much cold can the chiller produce in an amount of time (here, every minute) in unit of kW.

- COP (Coefficient of Performance) is the ratio of Heat capacity rate to the chiller power consumption. This shows how many times the chiller can produce cold comparing how much power the chiller consume.

Heat Capacity Rate(Q)

- Formula:

$$\text{Capacity Rate(kW)} = \frac{Water\ density\left(^{kg}/_{m^3}\right) \times flowrate\left(^{m^3}/_{hr}\right) \times 4.19\left(^{kJ}/_{kg \times K}\right) \times \Delta chilled\ water\ temp(K)}{3600(^{hr}/_{s})}$$

For the Water density, look up at Internet of the average chilled water temp
http://www.peacesoftware.de/einigewerte/wasser_dampf_e.html
Δ chilled water temp =
[chilled water return temp(℃) + 273]K – [chilled water supply temp(℃) + 273]K

» Higher the heat capacity value is, better the capacity to produce cold.

Coefficient of Performance (COP)

- Fromula:

$$\mathrm{COP} = \frac{Heat\ Capacity\ Rate(kW)}{Power\ consumption(kW)}$$

» Greater the COP number is, better efficiency that chiller consume power to produce cold water.

Examples for Heat Capacity Rate and COP

- Take 2017-July-24 12:57p.m. data for example

ts	evaflow	CHR temp	CHS temp	Power	conflow	CWR temp	CWS temp
2017/07/24 12:57 PM	211.50m^3	11.24 ℃	9.04 ℃	109.207 kW	203.17m^3	31.34 ℃	33.77

- Heat Capacity Rate (kW) = (999.68844162593*211.50*4.19*2.2)/3600
  = 541.38 kW

- COP = 541.38/109.207 = 4.957

» Why is Heat Capacity Rate and COP being low?

THANK YOU